THE SIDEREAL MESSENGER.

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY.

FEBRUARY, 1888.

Thou Lord in the beginning hast laid the foundation of the earth and the heavens are the works of thy hands.

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The Messenger will be published monthly except for July and August.

Subscription Price per year (ten numbers), $2.

Communications should be addressed to the Editor, Northfield, Minn.

NORTHFIELD, MINN.:

CARLETON COLLEGE OBSERVATORY.

Entered at the Post Office at Northfield, Minn., and admitted for transmission through the mails at second class rates.

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VOL. 7, NO. 2. FEBRUARY, 1888. WHOLE NO. 62.

THE LICK OBSERVATORY.

BY EDWARD S. HOLDEN.

For the MESSENGER.

MY friend, the Editor of the SIDEREAL MESSENGER, has asked me to write an article on the Lick Observatory at this time, notwithstanding the fact that quite a number of excellent accounts have lately appeared in various places, which seem to me to cover most of the points of interest.

Much of what is here given will appear in Volume I. of the *Publications of the Lick Observatory* shortly to be distributed, but it may perhaps be of interest in its present form.

As very few observations have been made with the instruments, I can only speak of the history of the Observatory up to this time, and of its condition at present, when it is officially pronounced to be ready to begin its work.

SKETCH OF THE HISTORY OF THE LICK OBSERVATORY.

In 1874 Mr. Lick gave $700,000 to a Board of Trustees (Mr. D. O. Mills, President), to provide a telescope "more powerful than any yet made"; and "a suitable Observatory connected therewith" was specified in his second deed made in 1875.

Just before this time, Professor Young had been making observations at Sherman, in the Rocky Mountains, and Professor Davidson had made several reports on the fitness of the high Sierras as a site for an Observatory. Mr. Lick was advised to choose a mountain site for his new Observatory and was seriously considering the selection of a place near Lake Tahoe. This site was subsequently abandoned on account of the severe winters, etc.

In the fall of 1874 Mr. Mills came to Washington to consult Professor Newcomb and myself (then assistant to Professor Newcomb), and others in Washington.

The whole matter was thoroughly discussed between us

and a project for the buildings and instruments of the new Observatory was made. This was reduced to writing by me in October, 1874, and rough sketches were made of the principal buildings, etc., by Professor Newcomb and myself. As it was then a question whether "the most powerful telescope" should be a reflector or a refractor, Dr. Henry Draper's counsel was asked for and freely given. Sir Howard Grubb also gave much time to projects for the Observatory.

Finally Professor Newcomb was asked to go to Europe to see where glass discs of a large size could be had, and this journey was made in the early part of 1875. It was strongly urged upon Mr. Mills that Mr. Burnham should test the excellence of the various sites under consideration before a final selection was made. This suggestion was not carried out till 1879, however.

The position of Director of the new Observatory was provisionally offered to me at this time. When Mr. Mills returned to California, he found that Mr. Lick was not satisfied with the policy of his Trustees and after a time the Board resigned and a second Board was appointed. Mr. Lick was equally dissatisfied with the policy of the second Board and finally a third set of Trustees was selected in 1876, which has acted until the present time. On Mr. Lick's death, in 1876, many distressing legal complications arose, and it was not until 1879 that they were finally disposed of, and work on the Observatory was begun.

In 1876 I met Capt. Floyd, the President of the Lick Trustees, in London, and together we visited various observatories and astronomers. Capt. Floyd also spent some months on the continent on the same business.

In the meantime Mr. Lick had agreed to build his Observatory at Mt. Hamilton in Santa Clara county, on condition that the county should build a road to the summit. This road, 26 miles long, costing $78,000, was built in 1876.

The selection of Mt. Hamilton, rather than Mt. Diablo, Loma Prieta, St. Helena, or a mountain further south was made by Mr. Lick on the report of Mr. Fraser who has been the efficient superintendent of construction of the Lick Observatory from 1876 to November, 1887.

It 1879 Mr. Burnham was invited by the Lick Trustees to bring his six-inch telescope to Mt. Hamilton and to observe

double stars there, so that he could test the quality of the vision and compare it with that at Chicago, Hanover (N. H.) and Washington. Mr. Burnham spent August, September and part of October on the mountain, in camp. In a capital report to the Lick Trustees (1880) he gave the results of his work. It was found that the nights of summer and autumn, say April to October or November, were excellent both as to clearness of vision and as to steadiness. The daylight hours are less satisfactory. Mr. Keeler has lately shown that the vision in winter time is not specially better than that at lower elevations.*

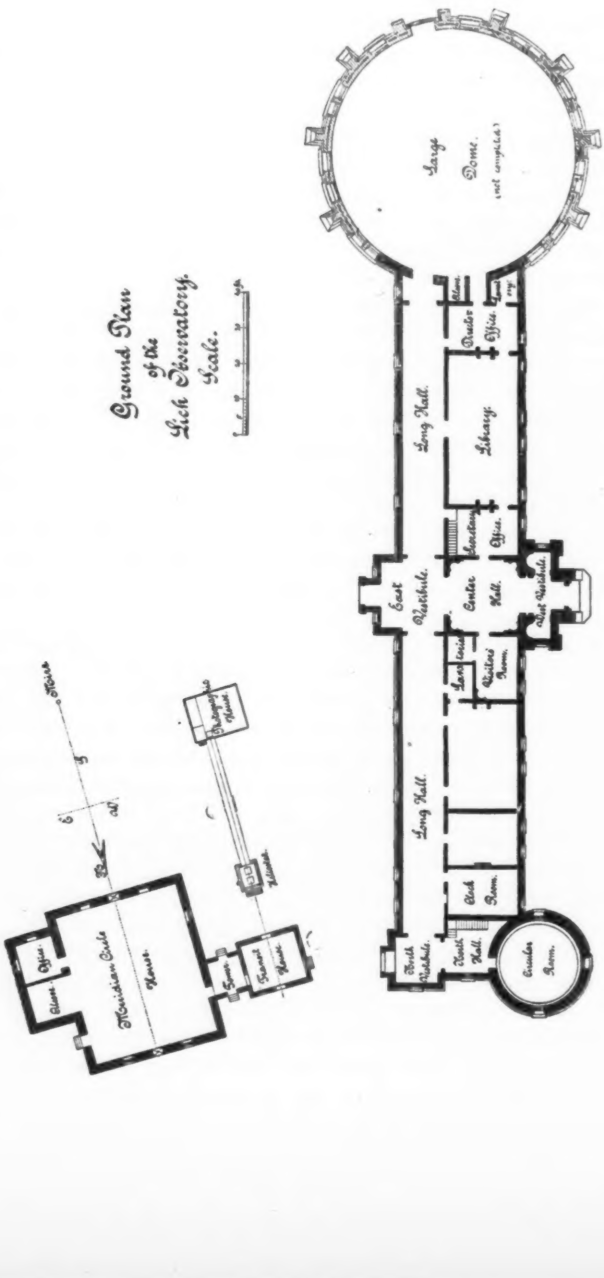
The secret of the steady seeing at Mt. Hamilton lies in the coast fogs. These roll in from the sea every afternoon in summer, rising 1,500 to 2,000 feet. They cover the hot valley and keep the radiation from it shut in. There are no fogs in the day time and few in the winter. Volume I. (before referred to) contains meteorological observations which throw much light on this and similar questions. I must simply refer to them in passing.

In 1879 Capt. Floyd and Mr. Fraser visited Professor Newcomb and myself in Washington and the plans for the Observatory were drawn. These are practically the same as those discussed in 1874.

The plans have proved to be entirely adequate and have been closely followed in most essential respects. Improvements have been made wherever it was possible, and many ingenious devices and details have been worked out by Capt. Floyd, or by Mr. Fraser, or by others under their direction. The plans for the buildings will be best understood by consulting cut on the following page.

At the south end of the Observatory is the 75-foot dome. At the north end is the 25-foot dome. They are connected by a hall, 191 feet in length. On the west is a series of study and work rooms. For the next twenty years there will be space in these rooms and in the hall for all the work of the Observatory. When it is necessary a second row of rooms can be built on the east side of the hall. I do not see any possible expansion of the Observatory which can not be provided for by such additional rooms, and by separate detached observing rooms in the immediate vicinity.

* Sidereal Messenger, Sept., 1887, p. 233.


Ground Plan
of the
Lick Observatory.
Scale.
Large
Dome.
(not completed)
Long Hall.
Library.
Office.
East
Vestibule.
Center
Hall.
West Vestibule.
Visitors
Room.
Long Hall.
Clock
Room.
North
Vestibule.
North
Hall.
Circular
Room.
Meridian Circle
House.
Office.
Transit
House.
Heliostat.

The building is of brick, painted. It has a slate roof. Tin was found to be better and has been used for the other buildings. Although the building is one story (with a shallow air space beneath), there is a great deal of floor room on the principal floor and in the low attic. The roof is also utilized by platforms and galleries.

THE DOME FOR THE THIRTY-SIX-INCH REFRACTOR.

The computations for the strength of the arches and of the walls of this dome were made by Prof. Bull, of Madison, Wis., in 1885, and forwarded to the Lick Trustees.

The contract for the dome proper was awarded to the Union Iron Works of San Francisco, in 1886, and the dome was finished in place in October, 1887. The details of plans were thoroughly worked out by Mr. Dickie, of the Union Iron Works, and by Mr. Fraser.

No adequate notion of the design can be had without woodcuts which I have no way of producing here. It may suffice to say that the outside diameter is 75 ft. 4 in.; the inside 71 ft. It stands on a smooth cylindric wall of brick 3 ft. 2 in. thick at base, 2ft. 3 in. at the top. This wall has few openings in it.

The original design of the brick cylinder, drawn by Prof. Bull from my sketches, is indicated on the plan of the buildings previously given. It provided for thorough ventilation and for rapid cooling off of the large masses of brick. This is a very important point and it is not yet certain that it has been secured by the modification actually adopted.

The dome itself is admirably constructed by the makers. The moving parts weigh 199,000 pounds, and can be set in motion by a pull of less than 200 pounds. That is, one pound can move 1,000. The usual motive power is obtained from a water engine which will rotate the dome 360° in less than nine minutes.

There are several novel features in the construction; perhaps the most important is the system of expansion bedplates for the track. The diameter of the dome changes one-half an inch in the extremes of temperature, and the track is given a smooth and oiled surface to slide upon (in and out).

The guide rollers are placed on the outside of this dome in-

stead of on the inside, as is usual. The shutter is a modification of the centre pintle shutter described by me in *Silliman's Journal*, in 1873. The modification is an admirable one and consists in placing the pintle eccentrically, so as to keep the shutter as near the dome as possible. Most of the bearings of axles in the dome are anti-friction (ball) bearings.

The shutters weigh	16,000 lbs.
Total weight of cupola	174,000 "
" " " live ring	25,000 "
" " " moving parts	199,000 "
" " " metal in dome	269,000 "
" " " elevating floor	50,000 "
Total number of rivets and bolts	250,000 "

The observing slit is nine and one-half feet wide. As far as can be known now, the dome is an entire success.

THE ELEVATING FLOOR.

A very ingenious plan was proposed by Sir Howard Grubb to the Lick Trustees for placing the observer at a proper height (any where from zero to thirty-seven feet above the floor). The idea was to have a portion of the floor move bodily up and down, like an elevator. This plan was adopted by the Lick Trustees and the floor has been built by the Union Iron Works. It is entirely satisfactory in every respect but one. My recommendation to the Lick Trustees was that the floor should move at the rate of four feet per minute. The motive power provided (a three-cylinder 8×6 water engine) requires ten times as long. It is probable that this speed can be materially increased by changes in the hydraulic arrangements, and if not the motive power can be replaced by steam or electricity, should the present speed be found materially too slow.

The moving floor is 61½ ft. in diameter and weighs 50,000 pounds, which is nearly all counterpoised. By suitable changes it is certain that the ingenious plan of Sir Howard Grubb can be made available and convenient. The speed actually required can hardly be definitely fixed until a series of observations have been made.

THE DOME FOR THE TWELVE-INCH EQUATORIAL.

This dome is a hemisphere 25 ft. 6 in. in diameter, made of thin plates of nickle-plated copper secured to a light framework of wood. The slit for observation is 3 ft. wide and

extends beyond the zenith. The shutter is part of a cylinder tangent to the sphere of the dome, and was made by Warner & Swasey in 1887. The mechanism for revolving the dome is novel, simple and efficient, and is the invention of Capt. Floyd and Mr. Fraser. An endless rope passes around the outside of the dome just above the base-plate, over guiding pulleys and down around a grove in a two-foot wheel placed in a recess in the wall of the room below. This wheel is rotated by a crank geared in the proportion of 3:1, and the friction of the rope on the outside is sufficient to turn the dome. To give the dome a complete revolution requires forty-one turns of the crank, and it can easily be effected in less than two minutes. The approximate weight of the dome is eight tons.

MERIDIAN CIRCLE HOUSE.

The Meridian Circle house, completed in 1884, from drawings made from my plans by Professor Comstock, is 43×38ft. with a wing 27×11ft. on the east. The walls are double throughout. The outer frame carries a louvre work of galvanized iron, which completely prevents the sun from striking any part of the building proper. The inner walls are of California redwood, and between these and the outer walls is an air-space twenty-four inches wide, which extends completely around the building. The ceiling is also of redwood. It is sixteen feet above the floor, flat in the centre of the room and arched over to connect with the side walls. A very large air-space above the ceiling communicates with the room itself and with the air-spaces of the walls. On the west the room opens into a ventilating tower two stories in height, which also adjoins and is connected with the house for the meridian transit instrument, which lies still further to the west. The design of this construction is to keep the temperature of the two houses and of their air-spaces precisely the same as that of the external air, and it is probable that this object has been practically attained. The upper room of the ventilating tower ought to furnish an admirable exposure for meteorological instruments.

The wing on the east side projects eleven feet from the main building, and contains an office room for the observer and an alcove to receive the glass house which protects the instrument when not in use.

The slit for observation is 3 ft. 4 in. wide. At the north and south it is closed by double shutters 20 ft. high, and overhead by four shutters, each 25 ft. long and 2 ft. wide, hinged at the side of the slit and opening outward. These shutters were devised by Mr. Fraser, are perfectly weather-tight and very convenient in use. They are the best that I have seen.

THE TRANSIT HOUSE.

The Transit house adjoins the Meridian Circle house on the west. It is built of iron with a wooden lining, after the manner of the Meridian Circle house, but the air spaces are smaller. The room measures 18 feet in an east and west and 14 feet in a north and south direction. The roof is arched, and the central opening is covered by a curved shutter, which is controlled by levers inside on the plan of Sir Howard Grubb. Sliding shutters on the north and south allow the instrument to point to the northern horizon and to the object glass of the photoheliograph which serves as a south collimating lens.

PHOTOGRAPHIC LABORATORY.

This is in a small wooden house with brick foundation, 16 ft. in an east and west and 12 ft. in a north and south direction, situated 60 ft. north of the Transit house.

The tube of the photoheliograph telescope enters the building $2\frac{1}{2}$ ft. to the east of the centre.

The laboratory is 13×12 ft. It is lighted by two windows, one of which is of red glass, in the west end. Both are provided with shutters. On the north is the brick pier which supports the plate-holder of the photoheliograph. A room on the second floor of the main building next to the 75-foot dome is also fitted for photography.

THE DWELLING HOUSES.

The astronomer's dwelling consists of a brick building 63×60 ft. and three stories high, situated on a level bench of ground excavated for the purpose to the eastward of the Observatory and about 22 ft. below the summit. A long flight of steps leads up from the plateau on which the cottages are situated to the principal entrance.

The building contains two distinct and precisely similar dwellings, which, however, may be made to communicate when desirable by doors in the partitions. The floors of the third story and the summit plateau are on the same level, and are connected by a bridge, which gives easy access to the Observatory.

SHOPS, BARNS, AND QUARTERS FOR ASTRONOMERS AND WORKMEN.

The cottages are situated on the saddle of the mountain connecting the Observatory and middle peaks, where a level place was cleared for the purpose. At the foot of the flight of steps leading up to the astronomer's residence is a large double cottage containing eleven rooms, formerly occupied by the superintendent. One large cottage and two smaller ones are but a short distance off, with sheds for poultry, etc. A little further along is a large barn with stables, and north of this a long, low house which has been used by workmen.

On the Observatory plateau, east of the main building is a low brick building containing a carpenter shop and separate rooms for oil, paints, a blacksmith's forge, etc.

As no one of the astronomical instruments has been thoroughly studied, the accounts which can now be given simply serve to accompany an enumeration of the instruments available.

Perhaps this is the best place to say that since 1886 Mr. Keeler has been employed by the Trustees in carrying on a time-service for California, etc. This extends as far east as Ogden and El Paso, and will shortly include Oregon, etc. Observations by Mr. Burnham, Professor Todd, Professor Comstock, Mr. Keeler and myself have thoroughly tested all the instruments except the large telescope.

Mr. E. D. Preston, of the U. S. Coast Survey, has determined the force of gravity at the mountain by pendulum observations.

TWELVE-INCH REFRACTOR BY ALVAN CLARK & SONS.

The objective and tube of this instrument were originally made by Alvan Clark & Sons for Dr. Henry Draper, and were mounted in his private observatory at Hastings-on-the-Hudson.

The objective is of the very finest quality. It was disposed of by Dr. Draper in 1879, in order that he might replace it by the photographic objective of 11 inches aperture, now at Harvard College Observatory. The objective was in the hands of the Messrs. Clark until September, 1880, during which time a substantial mounting was fitted to it. It was mounted at the Lick Observatory, in October, 1881.

THE SIX-AND-ONE-HALF-INCH EQUATORIAL.

(Objective by A. Clark & Sons; mounting by Warner & Swasey.)

In ordering the Repsold Meridian Circle it was stipulated that the three objectives of equal size which belonged respectively to the circle and to the two collimators, should be made by Alvan Clark & Sons. The north collimator is to remain always in position. The south collimator will be used in connection with it for determination of the horizontal flexure by the method of opposite collimators, but can be replaced for determinations of collimation by the south *mire*, about eighty feet distant.

Its objective thus becomes available for other purposes, and Messrs. Warner & Swasey have provided a portable mounting for this objective. It is the work of a few minutes to detach the collimator objective in its cell and to adapt it to the tube of the six-inch mounting. The cast iron column of this mounting is hollow and contains the driving clock and weights. It can be taken apart just below the clock for greater convenience in transportation when the instrument is used on eclipse or other astronomical expeditions.

The driving clock has several features of interest. The double conical pendulum is so hung that its period of revolution is very nearly independent of the height of the balls, which always assume the position proper to their velocity of rotation, although the retarding friction increases continually as the balls diverge. The performance of this clock is very satisfactory. A similar clock, with the addition of an electric control, is provided for the 36-inch refractor.

FOUR-INCH COMET-SEEKER BY ALVAN CLARK & SONS.

The objective has an aperture of four inches and a focal length of about thirty-three inches. The rays from the objective fall on a reflecting prism midway in the tube and

are bent into a horizontal plane. The observer has only to move his eye in azimuth while the telescope tube is moved in altitude, in order to cover the whole sky. The motion in altitude is effected by means of a crank. The instrument was ordered on the recommendation of Professor Newcomb in 1880, and delivered in 1881.

PHOTOHELIOGRAPH BY ALVAN CLARK & SONS.

The Photoheliograph is mounted due south of the Transit house. The Transit instrument serves to determine the position of the axis of the Photoheliograph; and conversely the Photoheliograph is used as a south collimator for the Transit.

It is essentially of the same form as those employed in the U. S. Transit of Venus expeditions of 1874 and 1882 which have been described (with plates) in the "American Observations of the Transit of Venus, 1874, Part I."

It was used by Capt. Floyd and Professor Todd to observe the Transit of Venus in 1882.

THE SIX-INCH REPSOLD MERIDIAN CIRCLE.

This instrument was ordered in 1882 and delivered in 1884. Previous to its dispatch to America it was thoroughly inspected by Prof. Auwers and by Prof. Krueger who were kind enough to do this at the request of the Lick Trustees. In a letter of May 6, 1884, Professors Auwers and Krueger say that: "The Meridian Circle ordered of the Messrs. Repsold is in its construction in every way suited to be the chief instrument in an observatory of the first class."

No description of the instrument and of the mounting need be given until after a series of observations shall have been begun and far advanced by its aid. Professor Comstock and myself observed with this instrument in 1886.

DECLINOGRAPH.

In April, 1885, Dr. Johann Palisa, of the Observatory of Vienna, kindly undertook to have a declinograph made which would fit either the 12-inch or the 6-inch equatorial. This instrument was delivered in 1886.

In 1885 it was my plan to carry the S. D. as far south as practicable and the declinograph was designed to aid in this.

As this great task is now in the able hands of Dr. Thome at Cordoba and of Dr. Gill at the Cape, the Lick Observatory has abandoned its original plan in this regard.

FOUR-INCH TRANSIT AND ZENITH TELESCOPE, COMBINED, BY FAUTH & CO.

This instrument was ordered, on the recommendation of Professor Newcomb, in 1880, and delivered in 1881. The aperture is 4.1 inches. It is essentially of the same pattern as the Meridian Circle of the School of Science at Princeton, New Jersey, by the same makers. It was mounted in October, 1881, and has since served for time determinations. In 1885 it was remodeled by the makers.

The objective (which is a very excellent one, by Alvan Clark & Sons) received a new cell. The eye-end was changed so that the micrometer can be used either in R. A. or Z. D. A sensitive level was added. In this way the instrument becomes a zenith telescope also, and can be used for an independent determination of the latitude by Talcott's method.

The piers were originally iron frames; they have been built solid with brick.

The east Y is movable in azimuth. The west Y is movable in level.

UNIVERSAL INSTRUMENT BY REPSOLD.

A universal instrument, by Repsold, was ordered in 1884 and delivered in 1885. Its telescope tube is broken at the middle where a reflecting prism sends the rays through the axis to the eye. Its aperture is 2.15 inches; the horizontal circle reads by two microscopes to 2″. The vertical circle reads by two microscopes to 2″. The circles are 10 inches in diameter. This instrument may serve for special investigations on the refraction; and it is a very perfect geodetic instrument. Together with the six-inch equatorial and a chronometer it constitutes an outfit which can be packed in a few hours and which is very suitable for astronomical expeditions. All these instruments pack readily into boxes of convenient size and shape.

CLOCKS.

There are two dead-beat clocks by Hohwu; two gravity escapement clocks by C. Frodsham and Dent; a mean time

clock for time-service work by Howard (dead-beat); several chronometers by Negus and a thermometric chronometer by C. Frodsham. It was originally intended to have a fine clock in each observing room, but a set of controlled clocks (Gardner's pattern) has replaced the finer clocks which are now in the clock room.

CHRONOGRAPHS.

There is a Fauth chronograph in the transit room, one in the meridian circle room and a Warner & Swasey chronograph in each dome.

MINOR INSTRUMENTS.

The Messrs. Repsold have furnished the Observatory with a level-trier of refined construction.

An engine for measuring photographs, scales, etc., has been made by Stackpole & Bro. from designs by Professor Harkness. It is similar to the one constructed for the U. S. Transit of Venus Commission.

For use in connection with the measuring engine, Professor W. A. Rogers, of Harvard College Observatory, has provided a standard bar 20½ inches long, containing a half-yard divided into inches and tenths, with two inches at one end minutely sub-divided.

A delicate spherometer, by Fauth & Co., is provided, beside resistance-coils, galvanometers, a disk photometer, small spectroscopics, spare prisms, eye-pieces, etc.

The most important of the minor instruments are the filar micrometer for the 36-inch, by Fauth & Co., the duplex micrometer, by Grubb, and a very powerful and convenient star-spectroscope made by Brashear from designs by Mr. Keeler.

Plans for a large solar spectroscope have been worked out by Professor Langley and myself, but the instrument has not been ordered as yet.

THE THIRTY-SIX-INCH TELESCOPE.

The visual objective is 36 inches clear aperture and 678 inches focus. One second at the focus is therefore about $\frac{3}{1000}$ of an inch. The image of the sun is about six inches in diameter. The photographic lens is more than 34 inches in aperture and about 48 feet focus.

The history of the objective is as follows: The flint disc was obtained from Feil in April, 1882. After nineteen failures, the crown was successfully cast in September, 1885. In 1886 a third (photographic) crown lens was purchased also from Feil, which was cast at the same time with the successful crown disc for the visual objective; it broke in the hands of the Clarks in 1886.

In 1887, the Trustees of Yale University kindly consented to sell their 27-inch flint disc to the Observatory for its cost to them, but the Messrs. Clark reported to Captain Floyd that this lens was of glass too yellow for a photographic corrector, and their liberal offer was not accepted by the Trustees. In 1887, Mr. Alvan G. Clark went to Paris and procured the crown glass from Feil, which has been worked into a third lens. The glasses have been thoroughly investigated by Professor Hastings and his results will be printed shortly.

The visual objective was completed by the Clarks and delivered in 1886, so that it has waited for a year for the dome and mounting.

The mounting is by Warner and Swasey and all the details of its construction have been worked out by them except those of the eye-end, which were drawn by Professor Bull, of Madison, from sketches by Professor Langley and myself.

The tube is nearly cylindric in shape, with a suitable port for access to the photographic focus. The counterpoising is arranged so that the photographic lens can be put on and taken off safely and quickly.

There are three regular finders 6, 4 and 3 inches in aperture. In addition to these, the 12-inch equatorial can be quickly attached as a pointer for photographic work should the controlled driving clock not prove satisfactory.

The following mechanical movements are provided:

An observer at the eye-end can

1. Clamp in declination.
2. Give slow motion in declination.
3. Read the declination circle (two verniers).
4. Clamp in right ascension.
5. Stop the clock.
6. Give slow motion in right ascension.
7. Read right ascension circle (one microscope).

An assistant on *either* side of the balcony below the axes can

8. Clamp in declination.
9. Give rapid motion in declination.
10. Give slow motion in declination.
11. Give quick motion in right ascension.
12. Give slow motion in right ascension.
13. Clamp in right ascension.
14. Stop or start the driving clock.
15. Read the right ascension circle (two microscopes).
16. Read a dial showing the nearest quarter degree of declination.

The original design of the makers allowed everything which is now done by an assistant on the balcony, to be done by a person on the floor.

The distance from the base of the iron pier to the centre of motion is 37 feet exactly, and to the lowest position of the (movable) floor is 35 feet 11 inches, leaving a clearance of 7 feet 10 inches for the eye-piece, or of about 3 feet 7 inches for the star spectroscope.

The eye-end is so arranged that the micrometer can be quickly removed, and two steel bars inserted in bearings. These bearings are part of a jacket around the eye-end. This jacket revolves smoothly 360° in position-angle. Spectroscopes, photometers, enlarging cameras, etc., can be readily attached to these bars. In this way this telescope mounting is made entirely convenient for micrometric, photographic or spectroscopic work. It is, in fact, three mountings in one. It is as yet too soon to pronounce any opinion on the telescope and mounting. The Clarks declare the objectives to be essentially perfect, and the mounting has been inspected by Capt. Floyd, Professor Newcomb, and Mr. Burnham, and pronounced satisfactory in every respect.

METEOROLOGICAL INSTRUMENTS.

The Observatory is not primarily destined for a meteorological station. Its very exceptional situation, however, creates a responsibility on its part to engage to some extent in making meteorological observations, and a suitable outfit for this purpose has been obtained.

A self-registering rain-guage, a self-registering barometer (Draper's pattern), and a self-registering wind-guage (U. S. S. S. pattern) are provided, together with two mercurial

barometers (by Green and by Roach), and a number of standard thermometers (by Green).

SEISMOMETERS.

A complete set of apparatus for the registration of earthquake movements has been provided by the Cambridge Scientific Instrument Co., from designs by Professor Ewing. The separate instruments are as follows:

(1.) A Horizontal Seismograph, with clock and driving plate. The clock is started by an electric contact at the beginning of the earthquake, and the two rectangular components of the horizontal motion are registered side by side on a moving plate.

(2.) A Vertical Motion Seismograph, to register the vertical movement of the surface of the earth on the same plate.

(3.) A Duplex Pendulum Seismograph, to give independent records of the horizontal motion on a fixed plate, the pencil being free to move in all azimuths.

(4.) A chronograph attachment which is set in motion at the beginning of a shock, and records the time of its occurrence by one of the standard clocks. It also marks the clock seconds upon the revolving plate of No. 1.

A catalogue of earthquake shocks in California from 1769 to 1887 has been compiled by me, and arrangements looking to a systematic registration of such shocks in various parts of California have been made.

CORPS OF OBSERVERS.

The Regents of the University of California have taken a most liberal view of the scope of the Observatory, and have provided for a corps of observers consisting, beside myself, of Messrs. Burnham, Schaeberle, Keeler, Barnard and Hill. A machinist and two laborers will also be employed. The work which has already been done by the astronomers is the best evidence that the instruments will be assiduously and intelligently used. The work which the Observatory will undertake can also be inferred from the list of the observers. It is hoped to extend the special facilities which the Observatory affords to distinguished observers of this country and abroad who are not officially connected with the establishment.

In this sketch, which is already too long, I have been obliged to pass over many things of real importance, and to merely mention obligations of the Observatory to individuals, which ought to be set out in full.

My object in what is here written has been to show the condition of the Observatory as regards its fitness for work, leaving to the more popular accounts which have appeared in various places, the history of the successive steps by which the desolate summit of a mountain 4,300 feet high has been turned into the site of one of the most important Observatories in the world. From the inception of the plan until now, this history will reflect credit on all who have been concerned in the work. Mr. Lick made the most splendid gift of the whole world to a noble science. The successive Boards of Trustees were composed of the best citizens of the state. The President of the present Board has given the best ten years of his life to make the Observatory a success, and he has been most ably assisted.

Astronomers all over the world have given their time and their advice generously without compensation.

The Regents of the University have agreed to maintain the Observatory in the most liberal and intelligent manner. They have provided a corps of astronomers who will do credit to the opportunity afforded to them. The press and the public of California have been most friendly to the undertaking.

We have now come to the final stage where results are to be looked for, and I can promise for myself and for my colleagues that we will spare no pains nor labor in that regard.

THE PLACE OF ASTRONOMY AMONG THE SCIENCES.*

PROFESSOR SIMON NEWCOMB.

When the astronomer of to-day contemplates the works of those who have gone before him and beaten the path for his footsteps he has every reason to be proud of the noble army which he passes in review. He studies the work of Possidonius, who several years before the Christian era stated the difference in latitude between Rhodes and Alexandria in Egypt: and who determined the magnitude of the earth within a limit of accuracy which we are hardly able to esti-

* Continued from page 20, January, 1888.

mate because we do not know how long were his measures of length. He also studies the work of Hipparchus, who first applied mathematics to celestial calculations, and showed how by trigonometry the motions of the planets could be investigated.

The astronomer of to-day remembers with sympathy the works of the Arabs, who, when Christendom was involved in darkness, kept burning the light of science, dim and feeble as their light was.

He is grateful to Copernicus who first demonstrated that the earth revolves around the sun and not the sun around the earth. He is grateful to Tycho Brahe, who built an observatory on one of the Danish Islands, and made the observation with which Kepler determined his famous laws of elliptical motion, and thus paved the way for a still further advance. He sympathises with poor Galileo, who, standing before the inquisition, was compelled to abjure the doctrine that the earth revolves on its axis and goes around the sun. He remembers him not only as the expounder of the Copernican system, but as one of the mathematical physicists who first made known the laws of motions which were still further to be used in the geometry of the heavens.

Then comes Newton, who, with a grasp which no mind has ever exceeded, shows how the laws of Kepler could be traced back to the laws of gravitation. His method of calculation is, of course, very far behind his age, but no less does he consider it worthy of his study: as the great warrior or king of to-day may yet consider worthy the doings of his forefathers.

He then thinks of La Place who, with his marvelous analysis shows how the theory of gravitation not only explains the motions of the heavens as we now see them, but can trace back the consequences of gravitation through hundreds of thousands of years, and show the various changes which went through the planetary organs long before man came upon the earth.

We must not forget in this connection the painstaking men of to-day who are, after all, only working on lines which have been gradually opening up to us for 2,000 years. None of the men whose work I have passed in review lived in vain. The most striking feature in the history of astron-

omical research is that the work of every generation and age in astronomy has been absolutely necessary to the study of that which followed it. This is not true in any other science. The chemist has nothing to borrow from the alchemist; he rejects all the alchemist's methods and ideas. The same is true in physics. The physicists began by rejecting all the ideas of the older physicists. But it is not so in astronomy.

To illustrate how this is: Suppose that from the earliest ages the earth had been enveloped in clouds—as it is probable from the results of the most recent observations the planet Venus is enveloped. So far as we can tell it is probable that the planet Venus is entirely surrounded by clouds so dense that no part of the solid body of the planet can be seen through them; the result is that the inhabitants of that planet (if there are any) can never see the heavens. If, then, we had been so situated on this earth, then we should never have had a sight of the heavens—never have had any knowledge of the existence or motion of the planets. We could, indeed, have inferred that a luminary went around the earth and worked out day and night; we could have worked out all the laws of physical motion on the earth, so far as the earth alone is concerned. Now, supposing that having done this, and these clouds had cleared away, and showed to our view for the first time the sun, moon and planets revolving in all their majesty, what would we have thought of the blue vault of heaven? We would have said: "This azure firmament is a solid globe which encircles the earth on which we live." Thus we should have had the system of the older astronomy as the very first thing to be presented to us. Then we should have found after a time that this revolution was attended with very singular inaccuracies, with a springing motion back and forth, and that springing motion would have next engaged our attention; and the conclusion would be,—here was an epicycle, one body revolving in an orbit which is carried around the earth day by day. That would have been the Ptolemaic school. But it could not have taken us five hundred years to go a step further; the very next generation would have discovered that this exceedingly complicated epicyclic motion could be explained by the theory that the earth and these planets all revolved

around the sun. But the same difficulties would have been met in receiving this theory as in the theory of Copernicus. It would have taken us a whole century even to admit it. Then, after a while, some Newton would arise to show that all phenomena are explainable by the laws of motion.

It has been sometimes said that astronomy was cultivated in the interest of astrology. I say there is no foundation in astronomical literature for any such opinion. In not one of the writings of the astronomers of antiquity or the Middle Ages have I ever found a sign of the belief of astrology. The astrologers borrowed their idea from the astronomers, and not the astronomers from the astrologers.

I have thus sought to present to you the two-fold aspect with which we may look at the scientific research of to-day. We have a literature requiring a skilled mind, and a science requiring long study, minute analysis, and all the other qualities which belong to the trained specialist; it is useful in many ways besides, in guiding the traveler on sea and land, by telling time. We have the work of astronomers as part of a great whole embodying those principles which are common to all the sciences; carrying the imagination through the universe, expanding our ideas of the world and its Creator, and calling forth our interest in generations yet unborn.

The actual, practical work of the observatory belongs, of course, to the useful class. And now, without entering into long details, it may not be inappropriate if I give a few hints respecting the details of establishments of this kind.

As you look upon our little building here, the first idea which strikes you is that it is an exceedingly modest establishment. You may, perhaps, doubt whether it will be looked upon with anything but pity by the astronomers of the world. Let me quote what was said by an eminent German. He said "The work was inversely as the magnitude of the institution. The really good work came from the small ones. The great ones did very little." (Applause.) The reason is not very far to seek. The observatory, after all, is nothing more than an instrument for the uses of a workman. If the workman is not efficient, your instrument is useless. He must not only be efficient, but must know what to do and be provided with the means

and incentives to do it. It was said that a skillful observer could do better work with a spy-glass attached to a cart wheel than an unskillful one with the very best appliances. The one motto which ought to be inscribed in every scientific institution of to-day is, that there is no such thing as mediocrity in scientific work; everything you do is worthless except the best. The observer may produce very little, but whatever it is it must be the best of its kind. He must, therefore, avoid doing too many things. I would like to tell you of the work of every kind which the astronomer of to-day is waiting to have done. The reason he is waiting is not from any lack of instruments, but rather from the lack of skilled observers ready and willing to devote themselves to small fields. There have been many failures from attempting to do too much, but none in attempting too little,—providing the little is not in the quality. When we read of researches such as those of the great Herschel, we are apt, perhaps, to picture to ourselves a gentleman comfortably seated at his telescope, through which he is looking at distant sidereal systems, giving free play to his imagination as he reflects over the possible inhabitants of some heavenly sphere. As a matter of fact we should have found him at the top of a ladder, standing on a platform, exposed to the wintry blasts of heaven, and, perhaps, impatiently waiting for a passing cloud to clear away.

The actual work of making observation is but a small portion of the work of an astronomer. He has to reduce his calculations, and few men find that interesting. Then there must be much matter carefully written up for the press, and the astronomer must show in his writings that he is acquainted with the work of his predecessors in paths similar to his own. Then must follow a long and careful examination of his work to show that it is all correct before submitting it to the judgment of his colleagues.

If the public are disappointed at not seeing brilliant discoveries coming from all the observatories, we must remember that what are called discoveries are not the main work of the scientific man of to-day. It would be too much to say with confidence that the age of great discoveries in any branch of science has passed by: yet, so far as astronomy is concerned, it must be confessed that we do appear to be fast

reaching the limits of our knowledge. True, there is still a great deal to learn. Every new comet that appears must be found by some one, and I do not grudge the finder the honors awarded him. At the same time, so far as we can see, one comet is so much like another that we cannot regard one as adding in any important degree to our knowledge. The result is that the work which really occupies the attention of the astronomer is less the discovery of new things than the elaboration of those already known, and the entire systemization of our knowledge. A few illustrations of this may not be out of place.

Last spring there met at the Observatory of Paris an international congress of astronomers and photographers. They met for the purpose of devising a method by which the stars of the heaven should be photographed. It may surprise you to know that of the millions of stars which are seen through the telescope we know no more individually than of the thousands of men who marched in the armies of Xerxes. They are not catalogued, and should one disappear from the heavens we should never know it. The greatest catalogue of stars yet numbers but about 30,000. With the most powerful telescope about 10,000,000 are actually visible. We see, then, that scarcely more than three per cent of the stars which can be seen belong to our knowledge. Only a small portion of them are found on the star maps, much less on the catalogue. Now, it is proposed by photographing the heavens to make a picture of the constellations as they are to-day, which shall perhaps include several millions of stars. This is a work in which it is eminently proper that the observatory should take part. But it will take very costly appliances and a whole corps of men working for many years.

The great discoverer, Sir Isaac Newton, introduced what we may call the mechanics of the heavens. Until the discovery of the spectroscope and the methods of photographing the heavenly bodies the astronomer had to work upon the same lines his predecessors had worked upon. Now the two sciences are coming together in closer and closer union. The new science of physical astronomy has been established within the last thirty years. The study of the stellar spectrum is a worthy one and quite within the reach of a very

modest instrument. I inquired of a specialist in this branch the other day if it was known whether the spectrum of the star Sirius changed as it went through the various stages of light. He said nothing certain was yet known on the subject. The determination of that required a very careful observer with all the best appliances at his command, and no one as yet had devoted the necessary attention to the subject.

It is the fashion to-day to dispose very lightly of the question "*Cui bono?*" when it refers to the value of scientific appliances. We take the value of all scientific work for granted, and look with a feeling akin to compassion upon a man who even seems to question it. I cannot entirely sympathize with this sentiment. Every inquiring person should know what benefit we expect to gain from scientific research. It is one of the vices of our time to take things for granted. Undoubtedly the science of the world has paid for itself many times over even in material benefit. It lies at the bottom of our civilization. Moreover it has got to be what it is by entirely ignoring the distinction between the useful and the useless. Now, you remember about a year ago one of the distinguished orators of our country defined a university as an institution where nothing useful was taught. We must understand that in this paradox the word useful was used in the sense of the ordinary man and not in the sense of the man of science. It was used probably in the same sense in which it is used in many regions of our country, where the people see nothing useful in any study for their children beyond the three fundamental branches of reading, writing and arithmetic. What I think Mr. Lowell really meant is that a university is a place where those things which the uneducated man considers useless are taught.

Now, it must be confessed that the distinction between the useful and the useless is entirely ignored in every form of scientific research. The astronomer takes as much interest in a map of the moon as of the earth; yet the knowledge of the lunar surface may never be of any benefit to mankind. Every addition to knowledge is a point gained, no matter whether any useful application can or cannot be made from it. One of the paradoxes of science is that all the useful branches which have been gained came by following out

the apparently useless. What more so than Galvani when he took the legs of a frog and showed how curiously they twitched under the actual contact with metals. Probably the men of his day thought he was simply playing; and yet, out of those little experiments have grown our science of electricity. The steam engine grew out of experiments on the boiling of a tea-kettle and the power of steam. The fact is, however, that it is impossible to say in advance whether any branch of knowledge will be useful or not. We do not know until we have found out what application may possibly be made of it. It seems almost as if nature withheld her choicest secrets from those who had only the useful in view. She seems to say, "You are investigating me in too low a state of mind. I will give my secrets only to those who investigate from a love of nature herself."

I suppose that if the pages of all our scientific literature of to-day were to be carefully scanned fifty years hence, or even if they were scanned to-day by experts in each of the separate branches, the verdict might be that only a small portion of the work they contain is really valuable knowledge. Not only does every work require a special aptitude, but one must be well acquainted with the sciences of the day in order to know what he ought to do and what to leave undone. An investigator going on unaided may obtain results already known, or hardly worth the publication. This tendency is also all the stronger because the whole spirit of modern investigation is in the highest degree a liberal one. We have no priesthood of science; we say to the world: find out all the knowledge you can, and publish it if you can; all that we ask for is the right to reject it if we find nothing at all in it; but we do not wish to dampen any future efforts of the kind.

The knowledge of the littleness of our place in the universe has done more for mankind, has been better for us, than any gratification of our material wants. A few centuries ago the appearance of a comet struck every one with terror; in the simple thought that we now look upon the celestial visitor with no feeling but admiration for its beauty, we have something which more than compensates for all the money and labor we have expended upon observatories and instruments. Are you not thankful to the astronomers that we

have a better idea of our place in the universe? There are other indirect benefits: as in every large city we open public squares and parks where the poor of the community may enjoy the fresh air of heaven, so it is good in the busy competition of our business life to have some moral breathing places which shall be free from those taints which affect this struggle for existence. He who enters an observatory or a museum finds an establishment all the attributes of which are placed freely there for him, without price placed at the disposal of mankind. Men like Agassiz and Faraday and Joseph Henry were animated with a love for nature for her own sake—they did not care for the honor of being known as inventors, they never applied for a patent for any of their discoveries, they made no restriction of their use, they had no other motive than that of helping the world.

I have thus sought in my imperfect way to show you a few of the aspirations which animate the astronomer. The motto which he may well recite is:

> "What need my Shakespeare for his honor'd bones
> The labor of an age in piled stones;
> Or that his hallowed reliques should be hid
> Under a starry-pointed pyramid?
> Thou in our wonder and astonishment
> Hath built thyself a lasting monument.

We can say with Horace, "Here is a monument more enduring than bronze."

A NOTE ON THE DISTRIBUTION OF THE STARS.*

W. H. S. MONCK, DUBLIN.

For the MESSENGER.

Having thus noted the mode of departure from uniformity as regards star magnitudes, I tried to ascertain the direction of the departure as regards right ascensions. I used the Harvard catalogue only for this purpose, the Oxford one being arranged in a manner inconvenient for the purpose. Treating the Harvard catalogue as complete up to magnitude 5.9 I found that the number of stars brighter than that magnitude were thus estimated in R. A. (from the North Pole to latitude 30° S.):

* Continued from page 25, January, 1888.

Limits.	No. Stars.	Limits.	No. Stars.
0h to 1h	108	12h to 13h	86
1h to 2h	116	13h to 14h	94
2h to 3h	115	14h to 15h	97
3h to 4h	147	15h to 16h	122
4h to 5h	169	16h to 17h	113
5h to 6h	174	17h to 18h	116
6h to 7h	159	18h to 19h	158
7h to 8h	132	19h to 20h	160
8h to 9h	106	20h to 21h	128
9h to 10h	91	21h to 22h	131
10h to 11h	84	22h to 23h	129
11h to 12h	89	23h to 24h	115

The influence of the Galaxy is here at once apparent. If the Galaxy was a band of uniform thickness the portion of it comprised in any hour of right ascension would be greatest at the points where it cuts the equator, and would then gradually diminish until it reached its greatest northern or southern declination, after which it would increase again. The influence of the Galaxy would therefore be most perceptible at the points where it meets the equator, and least so at distances of 6*h* in R. A. from these points. But as the Harvard catalogue does not include stars with a greater southern declination than 30°, the most southerly portions of the Galaxy are excluded from the list, and hence the minimum at this point falls much below the minimum corresponding to the greatest northern declination of the Galaxy. This minimum, in fact, gives what I may call the non-gallactic average, which seems to be about 87 stars above the 5.9th magnitude for each hour of right ascension. The excess of other hours over this appears to be due to the galaxy.

This enables me to make a rough estimate of the degree of comparative density of stars of this magnitude inside and outside of the limits of the Galaxy. At 87 stars for each hour of R. A., the total number of stars would be 2,088. The entire number in the table is 2,936, showing an excess of 848 due to the Galaxy. If we assume that the Galaxy covers one-tenth of the portion of the heavens included in the catalogue (which of course is only a rough estimate), the non-gallactic mean would give 209, while the actual number seems to be $209 + 848 = 1{,}057$. According to this estimate stars whose brightness exceeds 5.9 are about five times as numerous in the direction of the Galaxy as elsewhere.

The force of gravity varying like light according to the

inverse square of the distance, and the light which we receive from the stars comprised in any subdivision constantly increasing (at least up to the 5.9th magnitude), it seems reasonable to infer that the sun is probably not under the gravitational control of a small number of comparatively near stars, but of a great number of fainter ones. Since the stars between 4.8 and 4.9 give us more light on the whole than those between 1.8 and 1.9 (as is proved by their relative numbers), it seems probable that we are also more influenced by their attraction. And the great excess of stars in the Galaxy I think indicates that if the sun is moving round a centre, that centre must be sought for somewhere in the Galaxy. The point towards which the sun is moving is approximately known, and if we could assume that the orbit is nearly circular, we would find for its centre two alternative points in the Galaxy both distant by 90° from the point in Hercules towards which the sun is moving. And if one of these points was situated in an unusually thin, and the other in an unusually dense, portion of the Galaxy, there would be some reason to think that the latter contained the true centre of the solar system. But that the sun's orbit is nearly circular is an assumption for which there is very little evidence. Among the measured double stars eccentric orbits preponderate, and the great differences in the proper motions of stars whose distances from the common centre (if there be one) cannot be very different, renders the prevalence of circular orbits round this common centre improbable. Our own visitors from exterior space (if such they be), the comets and meteors, usually describe very eccentric orbits round our sun. The centre of the solar system, moreover, may not improbably lie in the rich southern portion of the Galaxy which is not embraced in the Harvard catalogue.

The following seems to me the most probable explanation of the facts respecting star distribution which have been enumerated. The nearer stars are non-gallactic, though some of them no doubt lie in the direction of the Galaxy. These non-gallactic stars are pretty equally distributed over the sky. Some of the gallactic stars, however, owing to their great masses and high temperatures, become confounded, even from the first, with the nearer non-gallactic stars. As we descend in the scale of magnitudes the gallactic

intruders become more and more numerous until at last we reach the average magnitude of the nearer gallactic stars, and may consider ourselves as dealing with the surface of a sphere which cuts into the Galaxy itself. At this point it is probable that the density of the stars ceases to increase, and that their distribution for some distance further accords pretty nearly with the law of uniformity; after which we begin to cut through the Galaxy in parts, and to reach a region beyond it where the density of the stars again diminishes. I think it is certain that the light of all the stars from the zero of the scale up to the 200th magnitude is not ten times as great as that of all the stars from zero to the 20th magnitude; but this may be due to some medium in space (perhaps dense flights of meteors) which intercepts or absorbs a sensible portion of the light of very distant stars. If no light is lost, even what I call the non-gallactic average cannot be maintained to infinity; but it seems likely that photometry has hitherto merely grazed the outer limits of the Galaxy, and that when it is carried two or three magnitudes lower what I have called the gallactic average will be found to have been exceeded.

In conclusion I may remark that the law as to the number of stars in R. A. will in this instance (and I believe in all other cases) become more apparent by taking the hours in pairs at distances of twelve hours from each other. The figures arrived at by this process are as follows:

Limits.	No. of Stars.
0h to 1h and 12h to 13h	(Minimum) 196
1h to 2h and 13h to 14h	210
2h to 3h and 14h to 15h	212
3h to 4h and 15h to 16h	269
4h to 5h and 16h to 17h	282
5h to 6h and 17h to 18h	290
6h to 7h and 18h to 19h	(Maximum) 317
7h to 8h and 19h to 20h	292
8h to 9h and 20h to 21h	236
9h to 10h and 21h to 22h	222
10h to 11h and 22h to 23h	213
11h to 12h and 23h to 24h	201

NOTE.—If we can rely on Argelander's catalogue as based on the ratio of 2.512 for each magnitude, the increasing density of the stars continues down to at least those of the 9th magnitude. The figures given by Sir Robert Ball in his "Elements of Astronomy" from Argelander are as follows: 1st magnitude, 20 stars; 2d, 65; 3d, 190; 4th, 425; 5th, 1,100; 6th, 3,200; 7th, 13,000; 8th, 40,000, and 9th, 142,000. The theoretic value of 2.512 is here exceeded in every instance save that of the stars of the 3d and 4th magnitudes; but neither the Harvard nor the Oxford catalogue sustains this exception.

The maximum interval here contains the two intersections of the Galaxy with the equator, and the minimum interval contains the poles of the Galaxy. Both increase and decrease are continuous, though the rate varies.

STANDARD DIMENSIONS IN ASTRONOMICAL AND PHYSICAL INSTRUMENTS.*

BY J. A. BRASHEAR, ALLEGHENY, PA.

In a paper read before the Franklin Institute by Mr. George M. Bond, the present secretary of Section D., the following words were quoted from Mr. Forney's report to the Master Car Builders' Association, on standard bolts and nuts:

"It is worthy of note that a remedy for the evil complained of by the Master Car Builders, that nuts, made by some firms, would not screw on bolts made by other firms, at first baffled the ability of the most prominent manufacturers of tools in the country, and to provide an adequate remedy it was necessary to secure the assistance of the highest scientific ability in the country, which was supplied through the co-operation of the professor of astronomy of the oldest and most noted institution of learning in the land. The man of science turned his attention from the planets and the measurments counted by millions of miles, to listen to the imprecation perhaps of the humble car repairer, lying on his back and swearing because a ⅝ nut a trifle small would not screw on a bolt a trifle large."

We all know this professor of astronomy and the noble work he has done in the way of giving us standards of the highest accuracy, which in turn have been carried out into practical mechanism by some of the honored members of the American Association, especially by Mr. Bond of the mechanical section.

Paradoxical as it may seem, though the astronomer has furnished the most accurate standards for the mechanician, thus facilitating the construction of interchangeable machinery all over the world, the astronomer himself has yet to put

*From the Proceedings of the American Association for the Advancement of Science, Vol. XXXVI.

up with an eye-piece that is just a little too large for a sliding tube that is just a little too small; or, in other words, that branch of science, which has furnished the standard for all other work, is without any standard for the construction of its own instruments.

How many of the parts of an astronomical or physical instrument should be made interchangeable, I am not now willing to say, but every worker with the telescope, spectroscope, or other instrument for physical research, will bear me out in this fact: that there is a sore need of standard dimensions in many of the parts of our apparatus. Indeed, our President, Professor Langley, was one of the very first to call my attention to the matter, and suggested that it would be a very excellent plan for the Association to appoint a committee to discuss, and, if possible, decide upon some standard dimensions of the more important parts which should at the earliest date be made interchangeable. I might urge many reasons in support of standard dimensions in many of the parts of our astronomical and physical instruments, but it is not necessary, as the day has passed when we are satisfied with anything but interchangeable parts in modern machinery; therefore we should not be satisfied with anything less for our astronomical and physical instruments.

As an illustration of what is needed, I have constructed four spectroscopes within the past year for six-inch aperture telescopes. The diameter of the tail piece of these telescopes has varied from two and one-half inches to six inches, requiring a new pattern to be made for every clamp that holds the spectroscope to the telescope.

We have indeed only to look at the great variety of eyepieces and their varied diameters for which we are constantly called upon to make adapters, so that they may be used with any degree of pleasure, to see how far we are from the ideal astronomical or physical instrument. We shall, in all probability, have to call to our assistace the "mandrel drawn" tube makers to give us standard tubes; and perhaps the founder to give us a standard metal, but we should make a move in the matter, and everything will come out right. These very mechanicians, to whom the astronomer has furnished the data, have given us standard reamers, standard guages, and every facility for making our own

work standard, and so we are without a subterfuge, without a valid excuse for doing our work in a "haphazard" way.

I should hope that whatever parts of our instrument we make of standard dimensions, that the basis should be a decimal system, preferably the metric; indeed, is it not possible that these standards might be made international as they should most surely be? The greater then the value of the metric basis.

This paper is only suggestive, but I trust will serve to call attention to a fault in the construction of our apparatus that is not in accord with the progress in other lines of mechanical art.

FIRST OBSERVATIONS OF SATURN WITH THE 36-INCH EQUATORIAL OF LICK OBSERVATORY.

BY JAMES E. KEELER.

For the MESSENGER.

The great telescope of the Lick Observatory was first directed to the heavens from its permanent home, on the summit of Mt. Hamilton, on the evening of January 3, 1888. A few observations of stars were then made for the partial adjustment of the object-glass, but rapidly thickening clouds prevented anything like a satisfactory test of its qualities. The next clear night was on the 7th, but the dome could not be turned, as the non-congealing solution, which will fill its "liquid seal," has not yet been provided, and everything had been frozen solid by a week of severe weather. It was consequently possible to observe an object only during its passage across the slit, but as this is sufficiently wide for half an hour's steady observation, no inconvenience was felt beyond the necessity of a little waiting.

Captain Floyd, Mr. Alvan G. Clark, Mr. Ambrose Swasey and myself were present at the trial. We observed a number of bright stars and doubles as they crossed the opening, and at about nine o'clock, the great nebula in Orion. Here the great light-gathering power of the object-glass was strikingly apparent. Only the central part of the nebula could be seen in widest field which could be used (power 312), but months would have been required to record satisfactorily all the intricate details which were there brought to view.

The opening in the dome was directed a little toward the east of south. The definition had been steadily improving, and when Saturn passed across the slit at a high altitude and entered the field of the eye-piece he presented probably the most glorious telescopic spectacle ever beheld. Not only was he shining with the brilliancy due to the great size of the objective, but the minutest details of his surface were visible with wonderful distinctness. Most of these I had repeatedly seen before with smaller instruments, but merely seeing an object, when every nerve is strained, and even then with half a doubt as to its reality, is very different from seeing the same object glowing with abundance of light and visible at the first glance.

How greatly the beauty of the view, even as a spectacle, depends upon sharpness of definition, was strikingly shown two nights later, when, although the sky was remarkably clear, the seeing was bad, and the view of Saturn was disappointing even to novices, the brilliancy of the image not compensating for its blurred and indistinct appearance.

After each of our party had taken his turn at the eye-piece, there remained some time for a more careful study of the details.

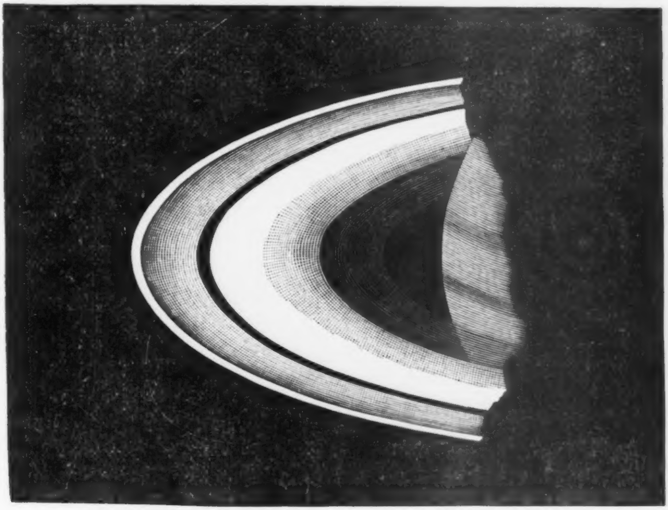
The outlines of the rings with a power of 1,000 were very sharply defined. The inner edge of the inner ring did not shade off gradually into the guage ring as often represented, although its brightness was there much diminished, but the line of separation was distinct, and I even thought that it was marked by a fine black division. The great aperture of the object glass brought out the guage ring with remarkable distinctness. It appeared uniform in tint, without spots or markings of any kind. Between its inner edge and the planet the background was perfectly dark.

The inner ring appeared as usual, with a shading increasing in depth toward its inner edge, suggesting an annular concentric structure, although presenting no definite markings.

The object of greatest interest to me was the outer ring. It is usually drawn with a division at about one-third of its width from the outer edge, sometimes fine and sharp and sometimes broad and indefinite. Many drawings which I have examined place this line or shade near the centre of the

ring. In a series of drawings which I made with the 12-inch equatorial of this observatory, from a careful study of Saturn during the finest nights of the past summer, the outer ring is represented with a faint broad shading in the centre, diminishing gradually toward the edges, which are therefore relatively bright.

The 36-inch equatorial showed, at a little less than one-fifth of the width of the ring from its outer edge, a fine but



SATURN'S RINGS AS SEEN WITH THE THIRTY-SIX-INCH EQUATORIAL, Lick Observatory, Jan. 7, 1888.

distinct dark line, a mere spider's thread, which could be traced along the ring nearly to a point opposite the limb of the planet. This line marked the beginning of a dark shade which extended inward, diminishing in intensity, nearly to the great black division. At its inner edge the ring was of nearly the same brightness as outside the fine division. No other markings were visible.

It is easy to see how, with insufficient optical power, this system of shading could present the appearance of an indistinct line at about one third the width of the ring from its outer edge. The broad band alone would make it appear near the centre of the ring, and the effect of the fine line, itself

invisible, would be to displace the greatest apparent depth of shade in the direction of the outer edge. Two nights after the observations just described I re-examined Saturn very carefully with the 12-inch equatorial, but could not perceive the narrow line, although I was then aware of its existence, and the definition was excellent. The appearance of the outer ring was exactly as represented in my earlier drawings. While I would not assert that the present structure of the ring as seen with the great telescope has existed for any great length of time, and has eluded the grasp of smaller instruments, I am confident that there has been no change during the past year.

There was no irregularity in the outline of the shadow of the planet projected on the rings, although Saturn was so nearly in opposition that the shadow was very narrow, and this peculiarity could not be so well noted as at other times. I have often noticed the distortion of Saturn's shadow when observing with the 12-inch equatorial, with a low power or on a poor night, but it always disappeared on employing a sufficiently high power, or with improvement in the definition. I have never been able to convince myself that it is anything more than a purely optical phenomenon.

The instrumental means at command on Mt. Hamilton have given me an excellent opportunity for testing the comparative efficiency of large and small telescopes under identical circumstances. The observatory possesses three equatorials, with object glasses of 6½, 12 and 36 inches clear aperture, all of Alvan Clark and Sons' best make. Objections have justly been made to the use of different apertures on the same telescope, and to comparisons of different telescopes when not made by the same person. My own eyesight is far from being acute, and I would not compare my observations with those of another person using even a much smaller instrument, but conclusions drawn from experiments made by the same observer, under the same circumstances, with instruments of the highest degree of excellence, differing only in size, are certainly valid. According to my experience, there is a direct gain in power with increase of aperture. The 12-inch equatorial brings to view objects entirely beyond the reach of the 6½-inch telescope, and details almost beyond perception with the 12-inch are visible at a glance with the

36-inch equatorial. The satellite of Neptune is to me always a difficult object with the 12-inch telescope, but it was very conspicuous with the great equatorial on the night of Jan. 9th, and if there had been another satellite of only one fourth or one fifth the brightness of the one already known, it could not have escaped detection. The great telescope is equal in defining power to the smaller ones, and has in addition the immense advantage of greater light-gathering power, due to its superior aperture.

Of course great size carries with it certain disadvantages. The telescope cannot be turned rapidly from one part of the sky to another, and observing is necessarily slow work, even with the most perfect mechanical appliances. It can however be employed on the work for which it is best suited, work entirely beyond the power of small instruments, while for these will remain fields of labor in which they will never be superseded by large ones.

FOR STUDENTS AND YOUNG OBSERVERS.

Interesting Phenomena for February.

Mercury is in the constellation of Pisces during most of the month of February. On the 13th at 4 o'clock in the morning it will be in conjunction with the moon; on the 16th it will be in perihelion, and at 3 o'clock on the morning of the 17th it will be in greatest eastern elongation from the sun, its distance being 18° 7′. The planet will not be in favorable position for naked eye observation, because so far in south declination. If clear to the horizon, it may however be seen for a few minutes near the time of the date last mentioned above.

Venus is in Saggitarius, near the star Pi, on the 16th. It is still very brilliant. During the last two months this planet has been unusually conspicuous in the southeast during early morning hours. Its great brightness has led many people to think that it was the Star of Bethlehem, so called, chiefly because some popular journals have been persistently claiming that such a star was now visible, and that it could be seen in the eastern morning sky. To persons unacquainted with the face of the sky, it may be said, that there

is now no unusual star visible, and that astronomers do not know anything about the Star of Bethlehem. The phenomena given in the New Testament, which no one disputes, have, however, never been satisfactorily explained on scientific grounds, for the probable reason that they were miraculous.

Venus will be in conjunction with the moon February 8th, and will enter the descending node February 27th.

Mars is among the small stars of Libra, a few degrees northwest of the star Kappa. He will be in conjunction with the moon February 2d, being at that time 2°51′ south.

The Minor Planets now number 271, the last being discovered by Knorre of Berlin October 16th. A charming little book giving full information about the minor planets has just been published by the J. B. Lippincott Publishing Company of Philadelphia, written by Professor Daniel Kirkwood of Bloomington, Ind. Notice of it elsewhere is more fully given. Since this book was published two of the recently discovered asteroids have been named: No. 268 is Adorea; 270 is Anahita. Nos. 269 and 271 are yet without names.

Jupiter is south and east of Beta Scorpii, and will move eastward during the month less than three degrees in right ascension. He will be in conjunction with the moon February 5th, being then 4°2′ south. The planet reaches quadrature, *i. e.* ninety degrees from the sun in right ascension, February 23d. Its apparent diameter is steadily increasing because the earth is approaching the planet, which will continue to be the case until the middle of the month of June, after which time the earth will pass by it and leave it behind.

Saturn is, for this month, a beautiful object for early evening observation. It is in the constellation of Cancer and makes nearly a right triangle with Pollux and Procyon. It slowly retrogrades during the month, and comes to opposition with the moon February 24th, being 1°22′ south. Readers of the MESSENGER will especially enjoy Professor Keeler's article in this number which gives detailed view of the great planet as seen through the 36-inch lens of the Lick Observatory.

Uranus is near Mars, being half a degree eastward and one degree north. Its motion is westward and northward. It will be in conjunction with the moon February 1st, the planet being then 4°29′ south.

Neptune is in Taurus, almost directly south of the Pleiades about six degrees. Its motion is slowly north and east. It reaches the point of quadrature with the sun February 15th.

The following table will also assist those who have small telescopes, and wish to know of the positions and motions of the planets for the month of February:

	R. A.	Decl.	Rises.	Transits.	Sets.
	H. M.		H. M.	H. M.	H. M.
MERCURY.					
February 5	22 08.0	−12°47′	7 66 A. M.	1 06.4 P. M.	6 17 P. M.
February 15	23 02.0	− 5 20	7 40 "	1 21.2 "	7 02 "
February 25	23 14.6	− 1 26	6 58 "	0 54.4 "	6 50 "
NEPTUNE.					
February 5	3 41.6	+17 54	11 24 A. M.	6 39.2 P. M.	1 55 A. M.
February 15	3 41.6	+17 55	10 44 "	5 59.9 "	1 16 "
February 25	3 42.0	+17 57	10 05 "	5 20.9 "	12 37 "
SATURN.					
February 5	8 17.5	+20 14	3 48 P. M.	11 14.3 P. M.	6 41 A. M.
February 15	8 14.4	+20 25	3 04 "	10 31.9 "	5 59 "
February 25	8 11.8	+20 34	2 22 "	9 50.0 "	5 18 "
URANUS.					
February 5	13 04.2	− 6 06	10 23 P. M.	4 00.2 A. M.	9 38 A. M.
February 15	13 03.5	− 6 02	9 42 "	3 20.2 "	8 58 "
February 25	13 02.6	− 5 56	9 02 "	2 40.0 "	8 18 "
MARS.					
February 5	13 41.2	− 7 51	11 06 P. M.	4 37.2 A. M.	10 08 A. M.
February 15	13 49.9	− 8 34	10 39 "	4 06.7 "	9 34 "
February 25	13 55.1	− 8 58	10 06 "	3 32.4 "	8 58 "
JUPITER.					
February 6	16 05.8	−19 56	2 24 A. M.	7 01.8 A. M.	11 40 A. M.
February 16	16 10.6	−20 08	1 50 "	6 27.2 "	11 05 "
February 26	16 14.4	−20 17	1 15 "	5 51.6 "	10 28 "
VENUS.					
February 6	18 38.3	−21 56	5 05 A. M.	9 33.5 A. M.	2 02 P. M.
February 16	19 30.3	−21 10	5 14 "	9 46.1 "	2 18 "
February 26	20 21.6	−19 22	5 17 "	9 57.8 "	2 39 "

Partial Eclipse of the Sun. A partial eclipse of the sun will take place on February 11, but will be visible only in regions south of 30° south latitude. Magnitude of greatest eclipse = 0.502 (sun's diameter = 1).

OCCULTATIONS VISIBLE AT WASHINGTON.

			IMMERSION.		EMERSION.		
Date.	Star's Name.	Magnitude.	Wash. Mean Time.	Angle f'm N. P't.	Wash. Mean T.	Angle f'm N. P't.	Duration.
			H. M.	°	H. M.	°	H. M.
Feb. 4	γ Libræ	4½	14 28	171	15 03	236	0 35
24	θ Cancri	5½	6 54	89	8 11	283	1 18
25	Ψ Leonis	6	15 40	127	16 36	273	0 56

PHASES OF THE MOON.

		Central Time. H. M.
Last Quarter	February 4,	1 25.7 P. M.
New Moon	February 11,	5 52.4 "
First Quarter	February 19,	7 59.2 "
Full Moon	February 27,	5 57.6 A. M.

MINIMA OF ALGOL (β Persei; R. A. 3h 01m, Decl. +40°31′).

	Central Time. D.	H. M.		Central Time. D.	H. M.
February	4	1 52 A. M.	February	18	9 57 A. M.
	6	10 41 P. M.		21	6 46 "
	9	7 30 "		24	3 35 "
	12	4 19 "		27	0 24 "
	15	1 08 "		29	9 12 P. M.

GREAT RED SPOT ON JUPITER—TIMES WHEN ITS ZERO MERIDIAN PASSES THE CENTRE OF JUPITER'S DISK.

	Central Time. D.	H. M.		Central Time. D.	H. M.		Central Time. D.	H. M.
Feb.	2	6 44.5 A. M.	Feb.	12	5 01.4 A. M.	Feb.	22	3 17.9 A. M.
	3	2 35.9 "		13	0 52.8 "		22	11 09.3 P. M.
	4	8 23.0 "		14	6 39.9 "		24	4 56.3 A. M.
	5	4 14.4 "		15	2 31.3 "		25	0 47.6 "
	6	0 05.9 "		16	8 18.3 "		26	6 34.7 "
	7	5 53.0 "		17	4 09.7 "		27	2 26.0 "
	8	1 44.4 "		18	0 01.1 "		28	8 13.1 "
	9	7 31.5 "		19	5 48.2 "		29	4 04.4 "
	10	3 22.9 "		20	1 39.5 "		29	11 55.7 P. M.
	10	11 14.3 P. M.		21	7 26.6 "	March	2	5 42.7 A. M.

PHENOMENA OF JUPITER'S SATELLITES.

	Central Time. D.	H. M.			Central Time. D.	H. M.	
February	4	3 26 A. M.	I Ec. Dis.	February	19	5 37 A. M.	I Tr. In.
		6 47 "	I Oc. Re.		20	1 42 "	I Ec. Dis.
	5	2 48 "	I Sh. Eg.			5 07 "	I Oc. Re.
		3 11 "	II Sh. In.		21	2 17 "	I Tr. Eg.
		4 00 "	I Tr. Eg.			2 48 "	II Ec. Dis.
		5 33 "	II Tr. In.		23	2 37 "	II Tr. Eg.
		5 41 "	II Sh. Eg.		25	1 51 "	III Ec. Dis.
	7	3 38 "	III Sh. In.			3 24 "	III Ec. Re.
		5 24 "	III Sh. Eg.			6 53 "	III Oc. Dis.
	12	2 28 "	I Sh. In.		27	3 35 "	I Ec. Dis.
		3 43 "	I Tr. In.		28	1 58 "	I Tr. In.
		4 40 "	I Sh. Eg.			2 55 "	I Sh. Eg.
		5 47 "	II Sh. In.			4 10 "	I Tr. Eg.
		5 55 "	I Tr. Eg.			5 21 "	II Ec. Dis.
	13	3 12 "	I Oc. Re.		29	1 28 "	I Oc. Re.
	14	5 06 "	II Oc. Re.	March	1	2 45 "	II Sh. Eg.
	18	2 52 "	III Oc. Dis.			2 45 "	II Tr. In.
		4 29 "	III Oc. Re.			5 12 "	II Tr. Eg.
	19	4 21 "	I Sh. In.				

THE CONSTELLATIONS.

At 8 P. M. in the middle of February the vernal equinox is very near the western horizon. There is no bright star at

this point. If we draw a line from the north pole to the vernal equinox it will pass very near to five bright stars: Polaris the pole star, γ Cephei, β Cassiopeiæ, α Andromedæ and γ Pegasi. This line is the equinoctial colure or first meridian from which the right ascensions of all stars are reckoned. The last two stars mentioned form the east side of the Square of Pegasus. Passing up toward the zenith from the Square of Pegasus one may trace the constellations Andromeda, Perseus and Auriga, the brightest star, Capella, of the last having just passed the meridian. Starting again with the west horizon, one may trace an irregular line of faint stars toward the east, along the equator for about 30°, to one a little brighter than the rest, then turning an acute angle and extending toward the north point as far as β Andromedæ. This V-shaped constellation is Pisces, The Fishes.

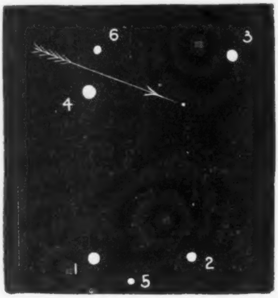
About 5° to the southeast from the point of the V, is Mira, o Ceti, the wonderful variable which, during most of the time, is invisible to the naked eye, but at intervals of about eleven months shines forth with the brilliancy of a star of the second or third magnitude. It is on the average about forty days from the time it becomes visible to the naked eye until it attains its greatest brightness, and it then requires about two months to become invisible. The next maximum will occur about the last of September 1888, although the period is so irregular that the exact date cannot be predicted. The minimum will occur in June. Passing east along the equator we may trace Aries, Taurus, with its two familiar groups the Hyades and Pleiades, Gemini, Cancer, with the planet Saturn, and Leo, the last extending nearly half way from horizon to zenith and marked by the bright star Regulus and the well-known group of the Sickle. On the meridian toward the south stands Orion, rich in objects for telescopes of moderate power. The great nebula in the middle of the dagger is in its best position to be observed. To the east from Orion are the two Dogs, Canes Minor and Major, and between them the One-horned Horse, Monoceros. Toward the north one may see the two Bears, the Dragon, Cepheus and Cassiopeia.

Studies of the stars with the opera glass, and methods of drawing the planets, Jupiter and Saturn, will be given next time.

EDITORIAL NOTES.

We are disappointed, and we are sure that President Holden will be also, in not seeing the leading article in this number illustrated by half a dozen fine cuts of the buildings and instruments of Lick Observatory. He certainly did his part in procuring the engravings, and THE MESSENGER waited ten days for them after they were due. They have not yet reached us. They may be somewhere in the snow drifts of Dakota, or possibly lost under those Northern Pacific banana trees of Montana, that we sometimes hear about. We have also had some apprehensions about this number of THE MESSENGER, coming, as it does, out of a cold wave, that sank us to 46½° below zero, by signal service reckoning in this latitude, lest it should go to our readers trimmed with icicles, or in the halo of thick ice fog.

Clark's New Star in the Trapezium of Orion. Mr. Keeler, of the Lick Observatory, kindly remembers THE MESSENGER with prompt notice of the first known discovery, by the aid of the great 36-inch equatorial. While Alvan G. Clark, was observing the Trapezium of Orion during first trial of instrument last month at Mt. Hamilton, he found an *exceedingly* faint star whose position is shown by the arrow in the above drawing. It was also seen, at the same time, by Mr. Keeler and Mr. Swasey, of Cleveland.



Saturn in the Great Lick Telescope. We give elsewhere, by the kindness of Mr. Keeler, the first view of Saturn, as seen through the great 36-inch lens of the Lick Observatory, at Mt. Hamliton, California, during the early days of last month. The fine drawing of the rings of Saturn furnished us by Mr. Keeler could not be reproduced in its delicate shading, by any procsss within reach, but that of lithographing. Our figure is only an approach in detail. The exquisite finish

of the gauge ring to definite inner outline, and the delicate changes of light and the faint traces of line divisions on the surface of the outer rings are the work of an artist's pencil rather than the possible effects of a well guided ruling machine. The drawing referred to represents a magnificent view of the Saturnian rings.

The Olbers Brooks' Comet. I send herewith three views of the above named comet selected from a number of sketches made at the eye-piece of the nine-inch reflector. Figure 1 shows its appearance on the morning of August 29, four days after my discovery of the comet. It was considerably brighter in appearance and the short bushy tail more pronounced. The nucleus was exceedingly diffused. Figure 2 shows the comet's appearance September 17, and a marked change in its form is noticeable.

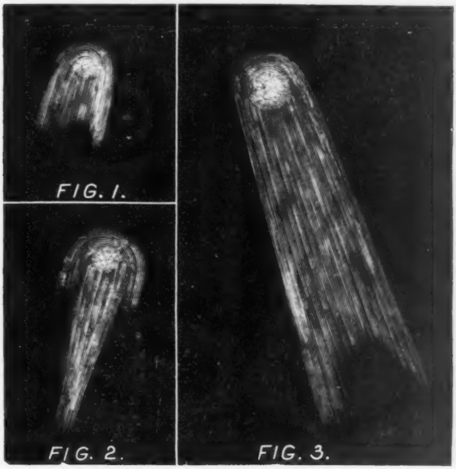


Fig. 3 gives its appearance on the morning of October 14th, about one week after the comet had made its perihelion passage, and was probably about at its brightest at this time. WILLIAM R. BROOKS.

Red House Observatory, Phelps, N. Y., Dec., 1887.

The above note should have appeared last month; it was accidentally passed in arranging for a form already late.

Professor Holden, as Associate Member of the Royal Astronomical Society. My attention has been called to a sentence in a letter from Mr. Richard A. Proctor published in

your issue for September last which I would desire to correct as being seriously unjust to Prof. Holden.

On page 261, Mr. Proctor says: "Prof. Holden owes it entirely to me that his name when suggested for a Foreign Associateship of the Society (*i. e.* the Royal Astronomical Society) was not rejected with contempt." As Mr. Proctor's remark conveys such an absolutely erroneous impression, I would solicit the favor of a little space to point out the facts of the case.

On 1884 May 9, Prof. Holden was nominated by the Council of the Royal Astronomical Society for election as Foreign Associate, and his certificate bears the signatures of *eleven* members of the Council, including the names of some most eminent in British astronomy.

Mr. Proctor had not been a member of the Council since February 1879, more than five years before.

On 1884 November 14, Prof. Holden was balloted for by the Fellows, and duly elected. It does not appear that Mr. Proctor was present on that occasion.

In selecting Prof. Holden for the Foreign Associateship, the Council desired to honor a distinguished American astronomer, and it is beyond question that that selection, and his subsequent election by the Society, could not in the remotest manner be considered as due to Mr. Proctor.

Royal Astronomical Society, EDW'D B. KNOBEL,
Burlington House, 1887, Dec. 17. Sec'y R. A. S.

Unjust to Professor Holden. We have also received a private letter from another prominent member and late officer of the Royal Astronomical Society, confirming in general way, the statements made in the above communication from Secretary Knobel. We hasten to mention these things in simple justice to Professor Holden, and to say that we were greatly surprised at the contents of these letters, and cannot now see, for the life of us, how it is possible for a man of Professor Proctor's intelligence and minute acquaintance with the active life of the Royal Astronomical Society to be ignorantly mistaken regarding the facts of Professor Holden's election. It is equally hard to believe that Professor Proctor could carelessly and confidently misconstrue the plain facts in so severe a criticism. In the light of these recent let-

ters THE MESSENGER greatly regrets the publication of what now seems to be both untrue and unjust to Professor Holden regarding his Foreign Associateship to the Royal Astronomical Society.

Professor W. Tempel. We were pained to learn from a private letter of Assistant C. W. Dunn, in the observatory at Florence, Italy, of the recent serious illness of Professor W. Tempel. Later news brings the cheering report that he is somewhat better, though still able to do only a little astronomical work. Friends are apprehensive that recovery at best may be slow.

The Star of Bethlehem. So good a paper as the New York *Evangelist* should read the stars in the sky rightly. Under date of Dec. 22 appears the following note:

> The "Star of Bethlehem," so called from its being coincident with the beginning of the Christian era, is at present visible any clear morning from about half past four. Its brilliancy far exceeds that of any other star. Its last appearance was several hundred years ago, and it will rapidly recede from the earth, not to be visible again for 340 years. Its light is so powerful that even after the sun has passed the horizon it can be seen. Look to the east.

The beautiful star referred to above was undoubtedly the planet Venus, which was at its brightest during the month of December, and to be seen in the south eastern part of the sky in the morning. Near this date it was visible in clear Minnesota skies all day. As for the Star of Bethlehem, astronomy claims to have no knowledge. The latest study of the Christian astronomer leads to the belief that the wonderful star-like appearance at the birth of Christ was a phenomenon wholly miraculous.

Preparations for Photographing the Sky. At a recent session of the Academy of Sciences at Paris, Admiral Mouchez gave the following report concerning the preparations which are being made for the execution of a chart of the heavens by photography:

"The preliminary researches and experiments are being made by the savants who were willing to take them in charge, and I have already received information that ten photographic telescopes conforming to the model of that of Paris, adopted by the congress, are actually in construction. They will all be finished next year or a little later, at the beginning of 1889.

"Here is a list of the observatories to which these telescopes are destined:

FRANCE—Observatory of Toulouse, Observatory of Bordeaux, Observatory of Alger.

SPAIN—Observatory of San Fernando.

BRAZIL—Observatory of Rio de Janeiro.

ARGENTINE REPUBLIC—Observatory of La Plata.

CHILI—Observatory of Santiago.

MEXICO—Observatory of Tacubaya.

AUSTRALIA—Observatory of Sydney, Observatory of Melbourne.

"The first seven are being constructed by the Messrs. Henry, for the optical parts, and Gautier for the mechanical parts; the last three by Mr. Grubb.

"It is possible that other instruments are in construction by other makers, but I have not been informed of any.

"We can count certainly on the coöperation of one or two observatories in England and upon the establishment, at least temporarily, of a photographic observatory in New Zealand, in accordance with the view expressed by the Congress. We can count also on the observatory of the Cape of Good Hope, whose eminent and active director, Dr. Gill, has contributed so much to the progress of celestial photography.

"I have equally good hopes in Russia; the concurrence of its observatory of Poulkova, because of its northern latitude, will be very desirable.

"I have received no news from Italy, Austria or Germany.

"In the United States several observatories seem to desire to take part in the work; but, as yet, I have not received any word of the order of a special instrument. The observatory of Washington will, without doubt be provided.

"We are to-day perfectly certain of being able to begin active work upon the chart of the sky in 1889, with a number of observatories already sufficient to undertake and finish, within the prescribed limits of time, the work of such vast importance, voted by the congress." H. C. W.

Harvard and Oxford Photometry. Before the publication of Professor Pickering's comparison of the Harvard and Oxford Photometries, I was engaged in comparing the same

catalogues, and I communicated my results to the Royal Astronomical Society before Professor Pickering's paper reached this country, though my paper was not read until afterwards. As there are some differences between my results and his, the publication of the former may prove of interest to some of your readers. I should premise that I took the stars comprised within certain limits of magnitude from the *Uranometria Nova Oxoniensis* and compared the values in the *Harvard Photometry*, while Professor Pickering adopted the reverse course. This difference in procedure will account for some slight differences in our results, but the differences are, I think, greater than might have been anticipated.

First, Professor Pickering seems to think that though the Pole Star is rated at 2.15 in his catalogue and at 2.05 in the Oxford one (being the standard star in both) the difference of scale is rather apparent than real. On the other hand by comparing the Harvard and Oxford values of a number of stars of pretty nearly the same brilliancy as the Pole Star, I came to the conclusion that the difference of scale is real, thongh perhaps it would be better expressed by 0.06 or 0.07 than by 0.10 magnitudes.

Second, I found that though this difference in scale steadily diminished, the stars were, on the average, brighter according to the Oxford measurements up to about the 4.30th magnitude, at which point the two scales coincide. Beyond this point the stars are brighter according to the Harvard table.

Third, Professor Pickering finds that after passing the 6th magnitude the stars become again brighter according to the Oxford observations. I did not find this to be the case. Taking the stars rated at 6.00 to 6.10, in the Oxford catalogue, and comparing them with the Harvard values, the latter appears to make the stars brighter on the average by 0.07 to 0.08. Below this point the number of stars comprised within any tenth of a magnitude in the Oxford catalogue were hardly numerous enough to warrant any positive inference but they rather indicated fluctuations or anomalies than any actual inversion. Thus from 6.50 to 6.60 the stars were brighter according to the Harvard estimate, while from 6.60 to 6.70 they were fainter. But the few stars lower than the 7th magnitude which appear in both catalogues

are again brighter according to the Harvard measurements. I concluded that the Oxford measurements made the stars fainter as long as the stars were numerous enough to justify us in striking an average.

I excluded from my computation the Oxford stars (given in the notes, not the text) in which a correction for atmospheric absorption was necessary. These stars exhibit such diversities as to lead me to think that the Oxford correction for absorption is radically erroneous.

May I venture to suggest that Professor Pickering (whose comparisons must have furnished him with the necessary data) will publish a comparison of the two catalogues, subdivided into tenths of a magnitude.

Dublin, Ireland, Dec. 17, 1887. W. H. S. MONCK.

An obvious error crept into my calculation of the relative motion of Sirius and his companion in the January number of THE MESSENGER. I believe I should be more accurate to say that the divergence of the curve obtained from measures of distance from that obtained from angles and epochs amounts in the segment of the orbit, between 60° and 30° to 0.62″. By the table near the bottom of page 26 it will be seen that the approach of the companion toward the centre of the system in passing from 60° to 30° is 11.50″—7.79″ or 3.71″. We must credit Sirius then in the same time with an approach of 0.62″, or one-sixth as much.

The table on page 27 should be reconstructed as follows:

Position Angle.	Dist. comp. as above.	Approach of Comes to center.	Approach of Sirius.	Distance Actual.
60°	11″.50			11″.50
50°	11″.26	0″.24	0″.04	11″.22
40°	10″.04	1″.22	0″.20 + .04	10″.80
30°	7″.79	2″.25	0″.38 + .24	7″.17

This of course makes the companion one-sixth the mass of the principal star, and they are, at the moment of their greatest apparent distance, respectively 9.87″ and 1.65″ from the center about which they both revolve. The semi-axis major in the table of elements needs a corresponding correction.

Such a mistake is decidedly "amateurish," but I will claim at least the credit of having discovered it myself.

NEWTON M. MANN.

Rochester, N. Y., Jan. 24, 1888.

BOOK NOTICES.

The Asteroids, or Minor Planets between Mars and Jupiter, by Daniel Kirkwood, Professor Emeritus in the University of Indiana. Philadelphia: Messrs. J. B. Lippincott Company, 1888; pp. 60.

The astronomy of the Minor Planets is given in full, with varied interesting details, in this small book just published by Professor Kirkwood. The subject matter appears in two parts, the first being a popular statement of the leading historical facts about the discovery of Ceres, Pallas, Juno, Vesta, and Astræa. In this part is given a table of all known planetoids down even to the date of this writing, the whole number, 271. This table contains the date of discovery, the name of the discoverer, the place of discovery and the name and number of the asteroids. The remarks that follow the table are instructive. A second table in the first part gives the elements of the orbits of the planetoids that have been computed, which are arranged in the order of perihelion distance. Part second is given to a discussion of the facts of this table last mentioned. The extent of the zone, the small mass of the asteroids, the limits of perihelion distance, stability of the zone, distribution of its members in space, commensurability of periods, particular perihelion distances, the second order of commensurability, chasms corresponding to the third order, chasms corresponding to the fourth order, relations to certain adjacent objects, the eccentricities, the inclinations, longitudes of perihelia, distribution of the ascending nodes, the periods, the origin of the asteroids, variability of certain asteroids, the average asteroid orbit and the relation of short period comets to the zone of the asteroids are the principal themes discussed in the last part of the book.

This little book deserves to be in the library of every scholar or seacher of science, who is interested in having the best knowledge of the asteroids. It will help the teacher of elementary astronomy to correct and amplify brief or misleading statements of the ordinary text-books on this subject.

Mitchel, F. A.: Ormsby Macknight Mitchel; Astronomer and General. Boston: Houghton, Mifflin & Co.; pp. 392.

This biographical narrative is one of exceptional interest, not only to any one who is fascinated by the well-told story of an eventful life, but also and especially to every one who has any adequate conception of the stimulus given to the

cultivation of astronomy in this country by Gen. O. M. Mitchel. It has been the author's aim to give the story, as far as possible, in his father's own words, by copious extracts from his diaries and other manuscripts. But much has necessarily been supplied by the author; yet the book is not a piece of literary patchwork. It is divided into two parts, entitled respectively Science and War. Part II is the record of a true hearted patriot and skillful soldier, who, despite lack of adequate support and the jealousy of his superiors, penetrated by swift and daring moves into the heart of the enemy's country, without leaving behind a sickening trail of desolation. But those interested in astronomy will find Part I replete with interest. Here we read Mitchel's own descriptions of his visits to the leading astronomers of the Old World: he gives pen portraits of them and descriptions of their observatories. The kindness of Sir George Airy and his wife, the courtesy of Arago, the good-heartedness of the bachelor Lamont, and the brusque hospitality and ruined hopes of Sir James South are set forth vividly. The heroic sacrifices and struggles which led to the establishment of Cincinnati observatory are depicted with graphic pen. The reader is also introduced to the charming family life of the subject of the narrative, and learns to admire and love him.

H. A. H.

First Steps in Geometry: A Series of Hints for the Solution of Geometrical Problems, with Notes on Euclid, Useful Working Propositions and Many Examples. By Richard A. Proctor. London: Messrs. Longmans, Green & Co., and New York: 15 East Sixteenth Street, 1887; pp. 179.

There is no doubt but that a working knowledge of geometry is, or ought to be, the principal thing sought by the student, especially after he has acquired some knowledge of geometrical methods and principles. When the author of the book before us says that teachers and books strive to impart readiness in following demonstrations rather than facility in obtaining solutions, he must mean those students who have already acquired some knowledge of geometry, and so have some foundation for independent, individual effort. As pertaining to this stage of advancement, the criticism is just, and to such the book is a help, containing as it does, many pertinent suggestions coming from experience and thought in the solution of quite a range of elemental geometrical problems. The notes on the propositions of Euclid's first two books are useful reading for teacher or student.